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WILLIAMSBURG, VIRGINIA

PROGRESS REPORT FOR NSG 567-A

April 1, 1965, to September 30, 1965

During the above period the High Energy Group completed two experiments at the Carnegie Tech cyclotron. The lifetime of the positive pion has been measured with ten times the best previous precision and a paper has been submitted to and accepted by Physics Letters for publication in the November 1, 1965, issue. A preprint of this paper is attached to this report.

The analysis of the negative muon capture rate data for heavy elements has been completed and a paper summarizing the results of the experiment and analysis will be submitted for publication within the next few weeks. This work indicates that a very satisfactory fit to the data can be obtained using the Fermi gas model for nuclei.

Muon Capture and Helium (J. Kane, D. Buckle, B.Orrick, R. Wetmore)

The work on liquid helium scintillation counters is proceeding with the immediate objectives of (a) preparing the large (two liter) counter for muon capture-polarization experiments and (b) preparing the small counter with pure gas system for experiments with pi and mu-mesic x-rays in helium and muon capture in helium 3. All of the equipment for the pure gas system has arrived and is in process of assembling.

Mesic X-Rays (M. Eckhause, R. Welsh, R. Harris, and W. Shuler)

Tests on commercially available li-drifted germanium detectors indicate that these devices will be very suitable for measurements of mesic x-rays. The detector on hand shows a resolution of less than 5 kilovolts at 1 MeV and has a large volume (5.5 cc). Initial tests of efficiency, stability, etc., are in progress, and it is planned that x-ray experiments will begin next year.

Instrumentation Development (M. Eckhause, R. Siegel, W. Sapp, F. Schneider)

Work is proceeding on the fast time of flight system for meson beam analysis and on the spark chamber work. The time of flight system works with <1 nsec resolution. The modular spark chambers (1 foot square) work very well and a readout system is being developed.

Attachment

A New Measurement of the Lifetime of the Positive Pion*

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The lifetime of the positive pion has been measured by a digital timing technique for pions stopped in a plastic scintillation counter. Use of this method has permitted improvement in precision by more than an order of magnitude over previous measurements.[1]

The counter arrangement is shown in Fig. 1. Pions from the Carnegie Tech cyclotron were brought to rest in counter "π" at the rate of 250/sec. A second scintillation counter ("μ") was optically separated from "π" by a thin (0.0005") sheet of aluminized plastic. A sizable fraction of the muons from pions decaying in counter "π" (thickness 0.032 in.) penetrated into counter "μ". Thus the pion stop signal and the muon decay signal occurred in different counters, permitting measurement of the time interval for each decay event by means of a 100 Mc/sec digital time analyzer.[2]

Fast coincidence logic (10 nsec resolution) provided a pion-stop signal $12\pi\widehat{\bar{\mu}\bar{5}}$ which opened the gate of the digital timer, and the gate-closing signal was then the decay muon signature $\mu\bar{5}$. Counter 5 was placed as close as possible to counter "μ", and served to suppress background due to beam particles, and positrons from the decay of stopping muons. Counter 5 also suppressed background arising from π-μ-e decays in which the stopping pion opened the timing gate and the positron closed it.

A total of approximately 10^7 π-μ decays were recorded. Of these, about 2.5×10^6 events with time intervals between 40 and 250 nsec after the pion stop signal were used in the analysis. The decay spectrum of π-μ events with lifetimes less than 40 nsec displayed anomalies related to the finite resolving time of the circuitry, and was not included in the analysis.

The digital timer included protective circuits which prevented storage of events in which two pions stopped within the maximum period of analysis (4 μsec), as well as circuits to insure that uncorrelated background presented a zero slope at all input rates. Possible non-uniformity of channel widths was investigated in tests with uncorrelated start and stop signals, confirming channel uniformity to better than one part in 1000. Analysis also indicated zero slope for the random signals.

Fifteen separate runs comprised the experiment reported here. The total pion amplitude in the first 10 nsec-side channel analyzed was about 10^6 counts. After fifty channels the amplitude was 5×10^3, of which about 90% was a 2.2 μsec lifetime component, the remainder being "flat" background. The 2.2 μsec background was produced by positrons of the π-μ-e decay chain, and corresponded to events for which the muons failed to register in the counter "μ", but the positrons did.

Correction for the background was made according to the following considerations. At the instant of the pion stop signal (t=0), the only source of background positrons is muons stopping with the pion beam as beam contamination. After t = 0, positrons from the π-μ-e decay should increase with time for a few pion mean lives. In order to measure these effects, and thus ascertain the time distribution for the background, two "growth" runs were taken. For these runs, counters "μ" and 5 in coincidence closed the timing gate, while the same $12\pi\bar{\mu}\bar{5}$ opened the gate. The time spectrum then took the form characteristic of a parent-to-radioactive daughter decay. These "growth" runs were then used to predict the shape of the μ-e background under the π-μ decay curves, after subtracting linear background from each. The resulting π-μ curves could then be fitted by least squares analysis to a function of the form $Ae^{-t/\tau}$ to obtain τ, the lifetime of the pion. Each of the 15 π-μ runs was analyzed separately. Good statistical agreement among runs was obtained, and the chi-square value for each run was as expected, when the analysis of decay events started at 40 nsec or more after the pion stop signal. The weighted mean of the 15 runs yields the following value for the mean lifetime of the positive pion:

$$\tau_{\pi^+} = 26.01 \pm 0.02 \text{ nsec}$$

The uncertainty quoted is one statistical standard deviation. This result differs by two standard deviations from that quoted in reference 1, but is consistent with earlier measurements quoted therein.

In addition to ascertaining statistical consistency among runs and goodness of functional fit (acceptable X^2) for each run, an important test of the data was to confirm that the mean lifetime obtained was insensitive to the choice of time intervals used in the analysis. Fig. 2 is a plot of pion lifetime against early channel cut-off varied from 30 nsec to 140 nsec, with late channel cut-off at 250 nsec in all cases. The data show no non-statistical fluctuation of lifetime over this range.

We wish to express appreciation for the hospitality shown by Dr. R. B. Sutton and the staff of the Carnegie Tech Nuclear Research Center; to express thanks to Mr. S. Hummel for construction of the counters, to Mr. D. Makowiecki for assistance with the electronics, and to Dr. R. Carrigan for valuable suggestions.

References

1. J. Ashkin, et. al, Nuovo Cimento 16 (1960) 490.

2. M. Eckhause, R. T. Siegel, and R. E. Welsh, (to be published).

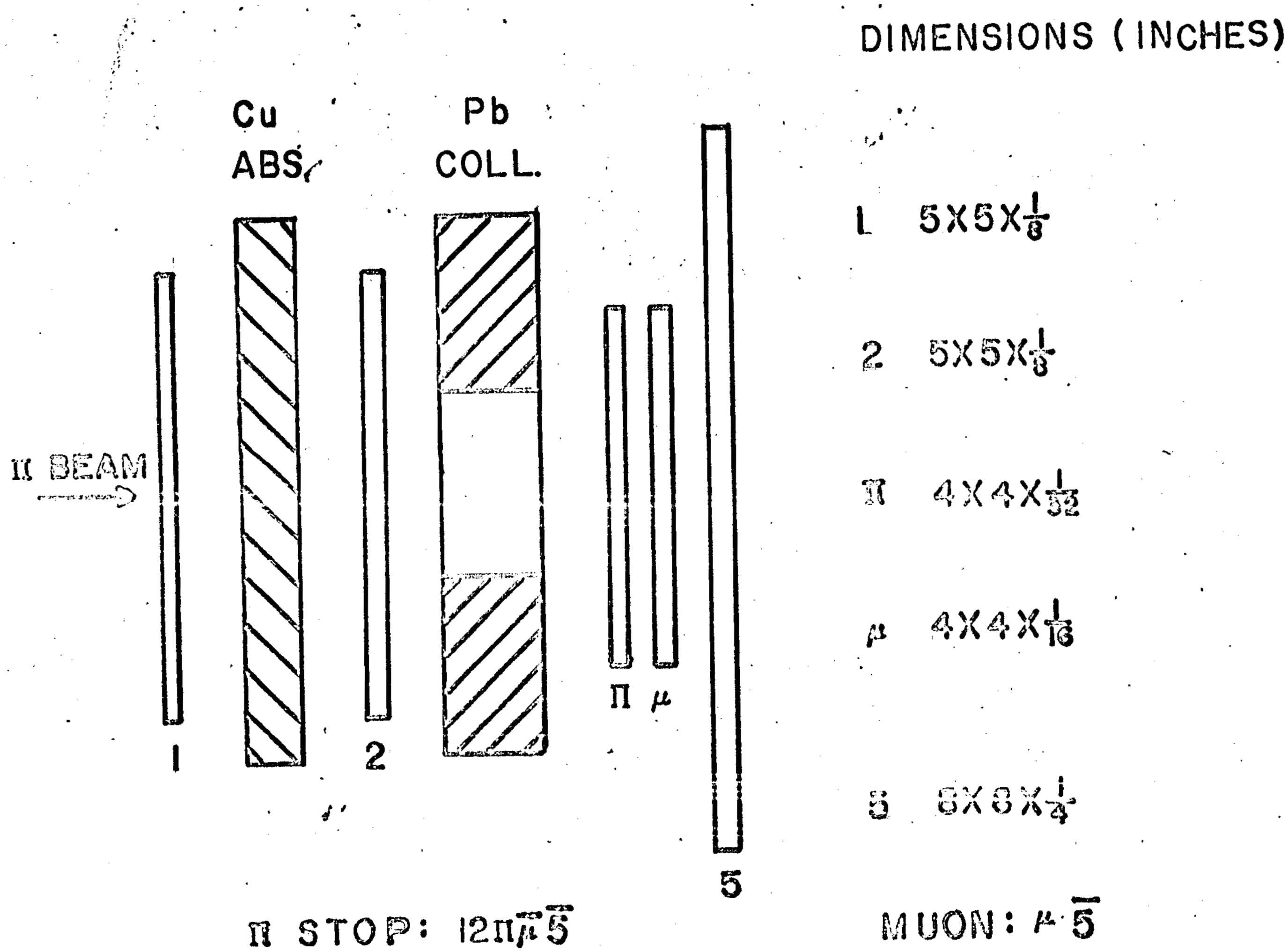

Fig. 1. Counter arrangement.

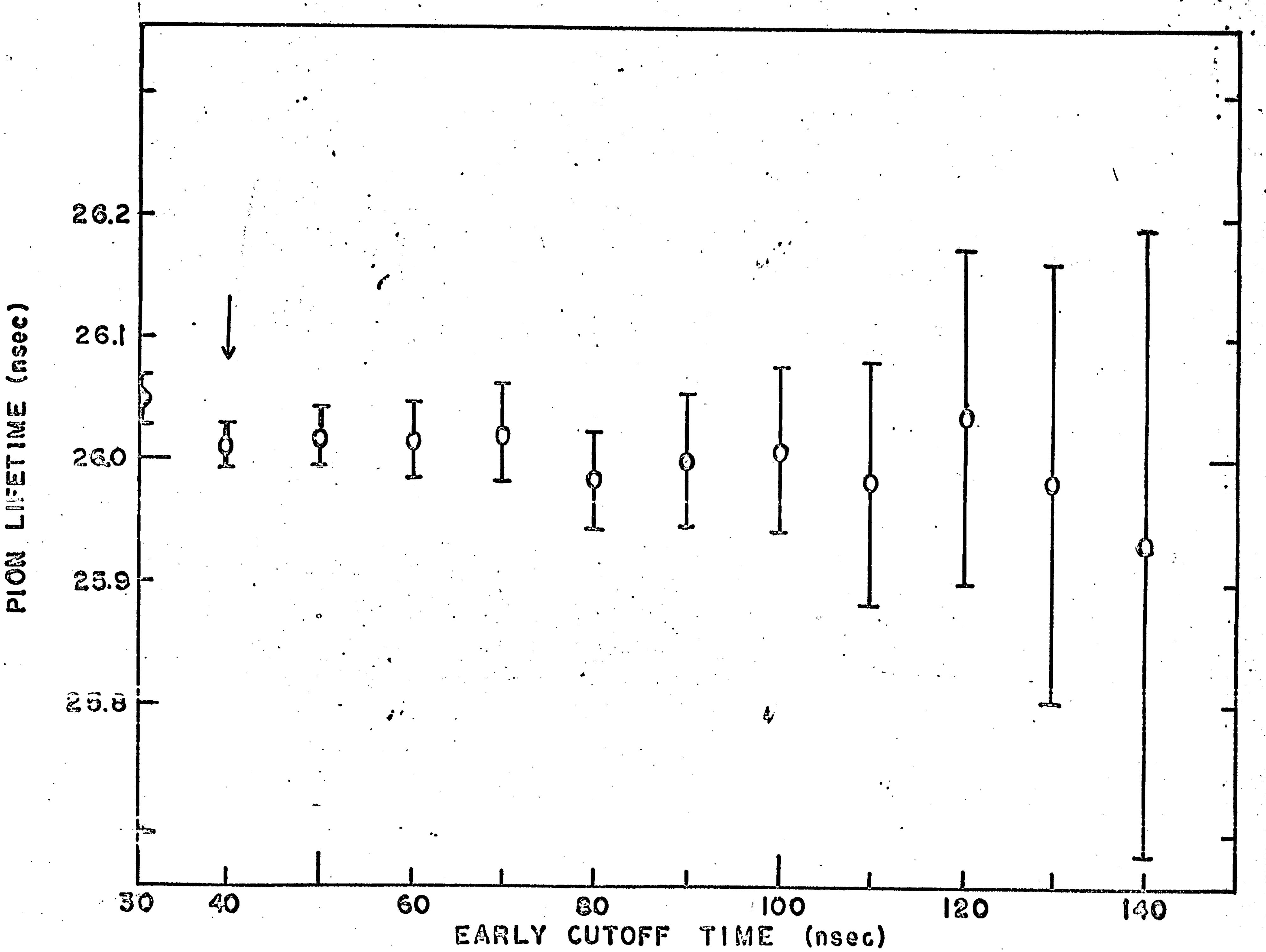

Fig. 2. Pion lifetime vs. early cut-off time.

PROGRESS REPORT FOR NSG-567-C
(April 1 to September 30, 1965)

During the past quarter funds assigned to NSG-567-C, "Miscellaneous," were expended in the following manner.

Travel to conferences and research consultations at other institutions:

Dr. and Mrs. Bruce L. Welch, AIBS Meeting (two papers presented), Urbana, Illinois.

Dr. Richard Terman, AIBS Meeting, Urbana, Illinois.

Dr. Melvin Pittman, Physics Conference, Denver, Colorado.

Dr. Stanley Williams, Psychology Conference, Chicago, Illinois.

Dr. Pincus Gross, Psychology Conference, Chicago, Illinois.

Dr. Peter Derks, Psychology Conference, Chicago, Illinois.

Dr. Virgil McKenna, travel to Princeton, New Jersey, research consultation.

Two lecturers were paid travel and expenses or an honorarium for lectures delivered at the College:

Dr. Charles Weiner of the American Institute of Physics.

Dr. Eliot Steller of the Institute of Neurological Sciences.

PROGRESS REPORT

TO THE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FOR

PROJECT NsG-567-E

"BIOLOGICAL EFFECTS OF RADIATION"

ROBERT A. PEDIGO
PRINCIPAL INVESTIGATOR

Notification of the award of $7,000 for support of the project Biological Effects of Radiation was received on January 21,1965. Since that time primary effort has been devoted to the purchase, installation, and licensing of a cobalt-60 laboratory irradiator to be used for this project. The license for the cobalt-60 irradiator was received on June 25, 1965 and installation of the source was completed on August 2, 1965. On Feburary 12, 1965 the principal investigator received an Atomic Energy Commission Grant of $11,000 for the instruction of radiation biology at the College. A portion of these funds were designated to include the cost of a cobalt-60 irradiator. It was therefore possible to pay for the irradiator partially with Atomic Energy Commission Funds and partially with NASA Funds. A portion of the $7,000 was subsequently diverted to support a graduate student and part time laboratory assistance as well as a few funds being used for research travel.

Experimental work has been conducted along several lines. First, the pine forest irradiation experiment at the Savannah River Plant has been continued. It is anticipated that the final measurements of growth will be made sometime this winter and a paper written concerning these effects sometime after completion of these measurements. The experiment involving the combined effects of drought and radiation on pine seedlings has been completed and the data are being analyzed for preparation of a paper. An additional experiment on the lethal dose for 1 year old pine seedlings has been initiated and is continuing.

As indicated in the proposal for continued support of this project emphasis is now being directed more to the cellular level of radiation effects. It has been possible during the summer to work out many of the problems surrounding tissue culture technique, but a number of other problems have arisen due to inadequate facilities. Solutions for these problems are currently being sought. Good success has been encountered with the growing of primary cultures of mammalian tissue, however, it has not been possible to establish a cell line for the organism used. Therefore the decision has been reached to continue radiation work on tissues of established cell lines. The first line that has been acquired is L-mouse tissue which is currently being grown in the laboratory. It is anticipated that future work will involve the use of established human cell lines. The laboratory techniques now used involve the treatment of the tissues with certain small molecules after irradiation. In order to insure the fact that these molecules enter cells dimethyl sulfoxide has been added to the cultures, since this compound has been shown to greatly facilitate the entrance of molecules into the cells. In an experiment involving plant tissues the addition of dimethyl sulfoxide to the media resulted in an increased growth of approximately

300 per cent. It is believed that this occurred as a result of the increased permeability of the cells to media molecules.

Work will be continued along the lines discussed above as soon as it is possible to make improvements in laboratory facilities.